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AN EXPERIMENT TO INVESTIGATE THE EFFECT OF THE GULF STREAM FRON--ETC(U)
JUL 75 C LEVENSON, R DOBLAR
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(6) AN EXPERIMENT TO INVESTIGATE THE EFFECT OF THE GULF STREAM FRONT ON LONG RANGE ACOUSTIC PROPAGATION.

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~~and~~
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INTRODUCTION

The Naval Oceanographic Office (NAVOCEANO) is conducting studies of temporal and spatial variability of the Gulf Stream system. Recently these studies have been extended to investigate the Gulf Stream's effect on long range acoustic propagation.

On 18 December 1974 an experiment to determine long range acoustic propagation through the Gulf Stream front was conducted northwest of Bermuda. Explosive charges were dropped from a Lockheed Orion P-3A aircraft along a loxodromic transit through the Gulf Stream. At the end points a series of 10 charges were detonated. Received signals from the charges were recorded from hydrophones located near Bermuda and analyzed for sound pressure level in one-third octave bands.

METHODS

The Gulf Stream's North Wall was located with an Airborne Radiation Thermometer (ART). A flight track was then selected that would situate the Stream normal to a bearing to the Bermuda hydrophones (figure 1). Thirteen Airborne Expendable Bathythermographs (AXBT's) were deployed along this line to measure water column temperature to 300 meters and to ascertain whether anomalous thermal features existed between the Gulf Stream and Bermuda. The aircraft then returned to Point "X" (figure 1) and detonated 10 MK-61-0 Signal Underwater Sound (SUS) charges, each containing 0.82 kg T.N.T., at a depth of 244 m. Additional charges were dropped at 11 km intervals along track XY to point Y, where another series of 10 charges were detonated.

Navigational fixes were taken during the SUS drops at two minute, (15 km), intervals with a Litton-51 (LTN-51) Inertial Navigation System. During the experiment the LTN-51 was accurate to within 2 km.

Acoustic signals were received at two hydrophones, amplified and recorded broadband on a Minicom C-100 seven channel FM recorder. Signals from each hydrophone were separated into high and low gain channels set 10 dB apart. Response of the overall system is known to an accuracy of $\pm$ 1 dB//1 volt RMS.

Recorded signals were filtered into one-third octave bands from 40 to 200 Hz and analyzed for RMS value over an 8 second period. The recording and analysis system are shown in figure 2.

RESULTS

Processed sound levels were normalized for spreading and attenuation losses using the relation $10 \text{ Log } R + \alpha R \times 10^{-3}$ where R equals range in yards and α equals attenuation coefficient in dB/kyd (Thorp, 1965). Figure 3 shows normalized values plotted for each shot in one-third octave bands centered at 50, 80 and 160 Hz. Mean and standard deviation at points X and Y are indicated. Statistical significance tests showed the means between points X and Y to be significantly different at a confidence level of 99.9%.

To relate received levels to physical parameters encountered, a temperature cross section between points X and Y was constructed from AXBT and ART data (figure 4). The AXBT measures temperature

to a depth of 300 meters with an accuracy of ± 1.5°C. The ART can accurately detect surface temperature changes as small as 0.5°C. Sonic layer depths were calculated from these data and are indicated in figure 4 along with Gulf Stream boundaries. It is customary to define the North Wall of the Gulf Stream as the intersection of the 15°C isotherm at 200 meters while the South Wall is more loosely depicted as the 1-2°C drop in surface temperature between Gulf Stream water and the Sargasso Sea water.

Representative AXBT's from each water mass (Slope, Gulf Stream, and Sargasso Sea) were also merged with deep historical temperature data from the Integrated Carrier ASW Prediction System (ICAPS) data bank (Hanssen and Tucker, 1974). Traces were extended from 300 meters to the bottom and sound velocity profiles derived using temperature and corrected historical salinity data for the area and season (Pickett, 1972). Figures 5, 6, and 7 show temperature, derived sound velocity profiles, and deep sound channel axis.

Ray plots were constructed using the GRASS model (Cornyn, 1973) to show acoustic propagation paths in water masses encountered and receiving hydrophones (figures 8 to 12).

DISCUSSION

Inspection of received levels (figure 3) indicates two areas where sound reception was attenuated. Shots 411 and 412 were received at levels too low to process while shot 413 was

not received at all (413 was possibly a dud). This suggests an area of poor sound propagation in the region of the south edge of the Stream which possibly is explained by sonic layer depths which were at or just below the depth of the explosions in this area. The ray plot diagram for this area (figure 11) with the source near shot 413 (figure 4) indicates a sound channel mode of propagation with rays occupying the channel from about 200 to 4000 meters. The angle and speed at which these rays are entering the sound channel is significantly less than those occuring within and north of the stream (c.f. figures 5, 6, and 7).

An area of low received values also occurs in the Stream near the North Wall. Received levels for shot 419 are low for the 50 and 80 Hz bands while shot 420 is low for the 160 Hz band (figure 3). In addition shots 421 and 423 were not received. Although these charges could have been duds the possibility that they were not received owing to thermal conditions should not be discounted. This seems especially evident in view of the consistent decrease in values from shots 424 to 419. Although the sonic layer depth does show a dip in this area it does not appear deep enough to significantly affect the shots. The ray plot from this area (figure 10) with the source near shot 422 also shows a sound channel type of propagation with rays spreading out between 200 and 4000 meters. This contrasts sharply with the plot constructed 25 nm from this area with the source near shot 425. This plot (figure 9) shows a mixed deep sound channel and convergence zone type of propagation with a compact bundle of rays occurring

between 500 and 2500 meters. This is markedly different from that shown in figure 10 and was associated with the highest levels recorded during the experiment (figure 3).

An area of high received levels was observed from shots dropped north of the Stream. This is consistent with the ray plot from this area (figure 8). The explosions are well below the sonic layer depth and the rays are propagated in the deep sound channel which increases in depth as it goes through the Stream and into the deep warm water of the Sargasso Sea. The result is a compact bundle of rays arriving at the vicinity of the hydrophones which theoretically contains 33% more rays than those arriving from the spread out sound channel mode of propagation generated from the area near the South Wall of the Stream (figure 11). Figure 12 shows the ray plot from a source near point X. The plot appears similar to figure 11, however, the recorded levels are much higher (figure 3). This suggests other mechanisms which may be operating to affect received amplitudes. Nichols and Young (1968) suggest that variations in amplitudes may be due to the diffracting effects of internal waves on multipath interference patterns. Lee (1961) has calculated that internal waves may produce intensity contrast as high as 20 dB. Kennedy (1969) comparing his experimental work with a theoretical model used by Chernov (1960) believes " the major effect of propagating through a layered nonhomogeneous medium is that the acoustic wave encounters a spectrum of 'patch' sizes as the wave cycles the ocean layers."

Results appear significant for ASW system performance in the vicinity of the Stream. Regions of low sound propagation associated with the Gulf Stream appear to offer excellent areas to escape long range detection. Conversely the area North of the Stream does not offer the same advantages.

Experiments are being planned to determine if these effects are seasonal and to ascertain propagation characteristics along lines other than normal to the Stream.

SUMMARY

Acoustic charges were detonated on a line normal to the Gulf Stream and recorded at Bermuda. Received signals indicate areas of poor transmission associated with the North and South Walls of the Gulf Stream. Conversely, high levels were received from charges detonated north of the Stream. These phenomena can possibly be explained by varying sonic layer depths and a deepening sound channel axis between Slope Water and deep warm isothermal layers of Sargasso Sea water. Other factors possibly related to amplitude fluctuations may be internal waves and "patches" of water different from surrounding areas. Further experiments to delineate seasonal and angular factors are being planned.

ACKNOWLEDGEMENTS

The authors express their thanks to A. Arneson and P. McLure of Tudor Hill Labs., Bermuda and to Lt. J. Nelson and the crew of Project OUTPOST SEASCAN for their aid in collecting and processing these data. They especially wish to thank W. Gemmill

of NAVOCEANO for his assistance in producing ray plots, analysis of data, and his critical review of the manuscript.

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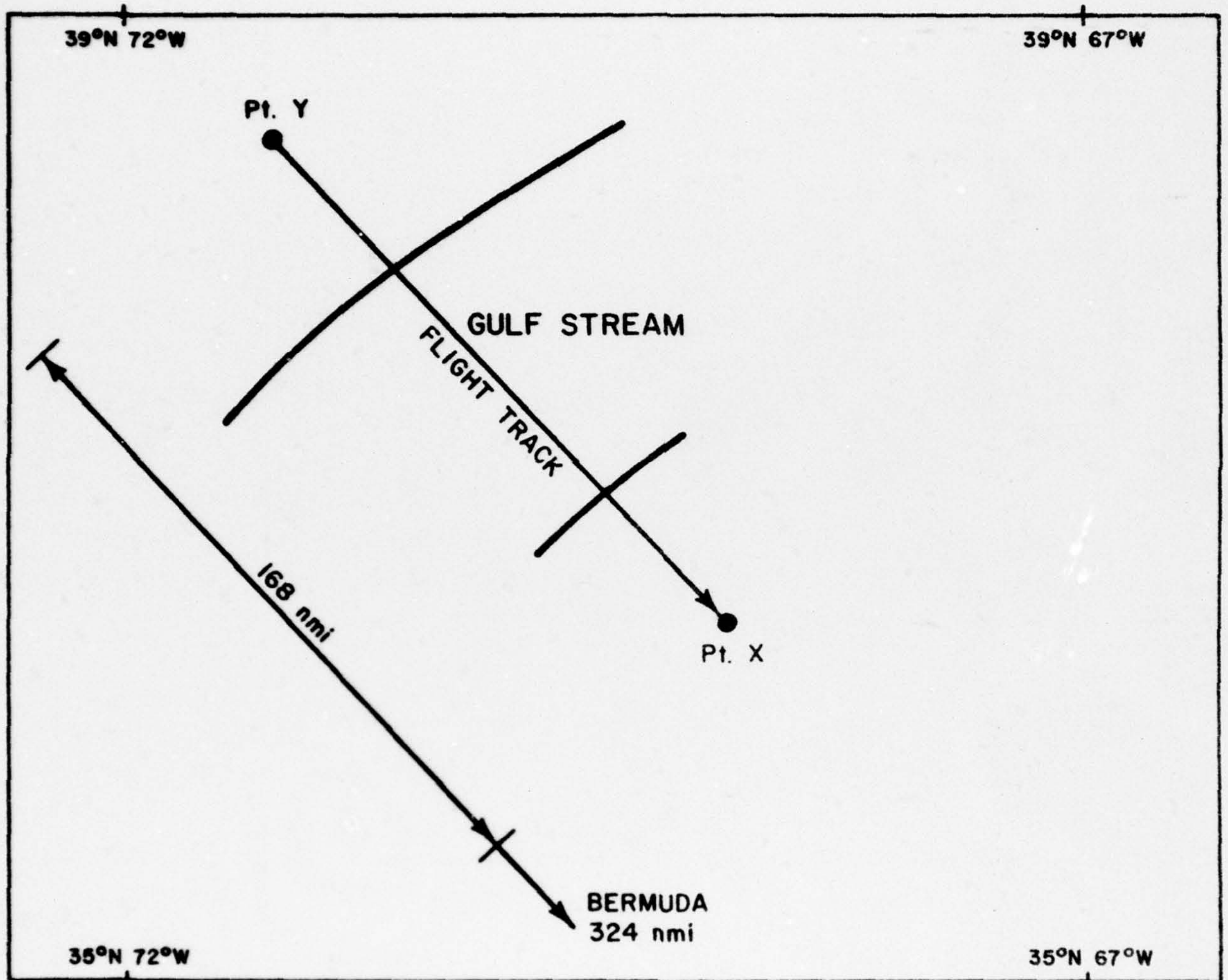

Figure 1. Aircraft flight track through Gulf Stream

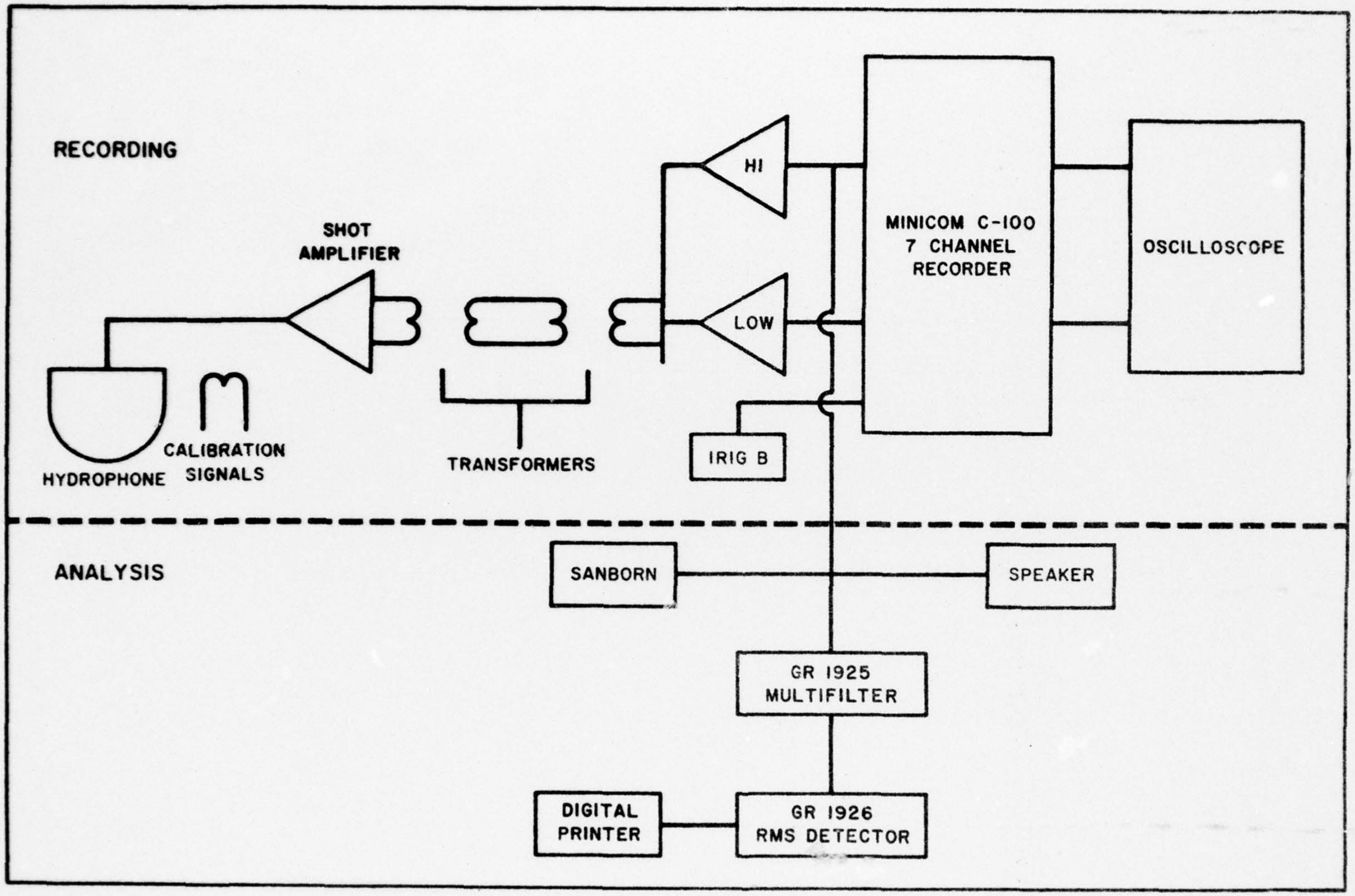

Figure 2. Recording and analysis setup

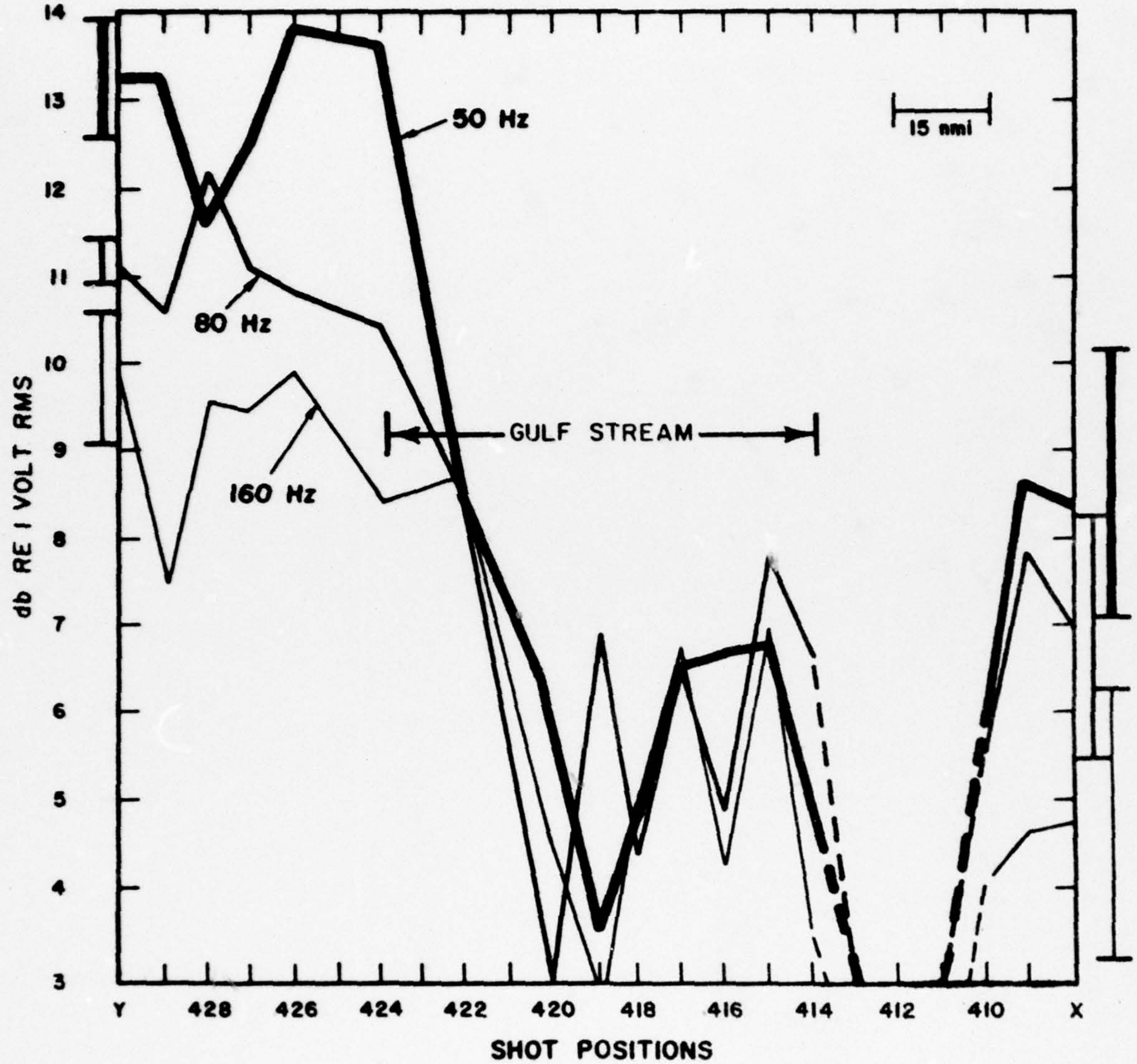

Figure 3. Normalized received levels in one-third octave bands at 50, 80, and 160 Hz

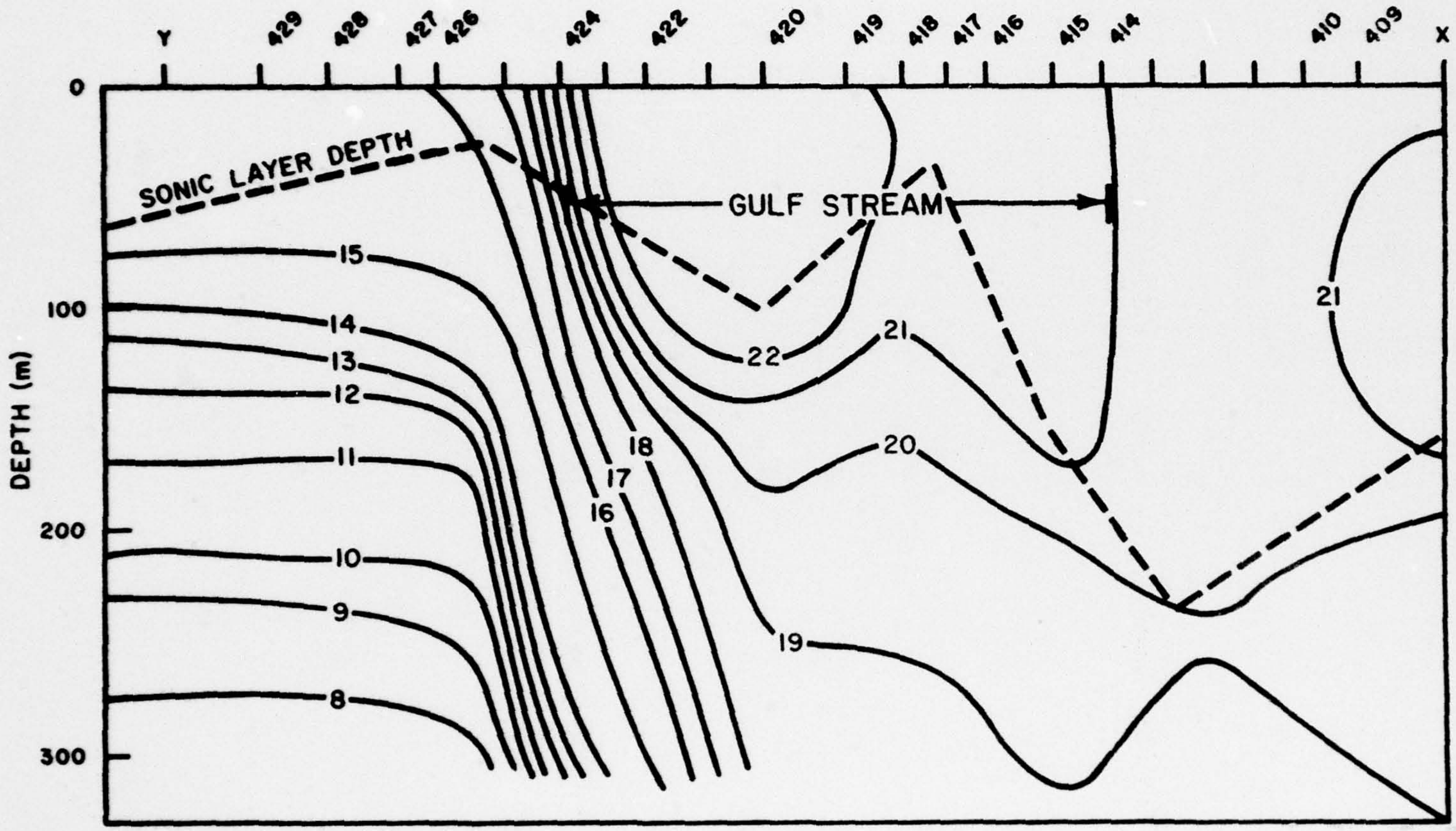

Figure 4. Temperature (°C) cross section and shot positions

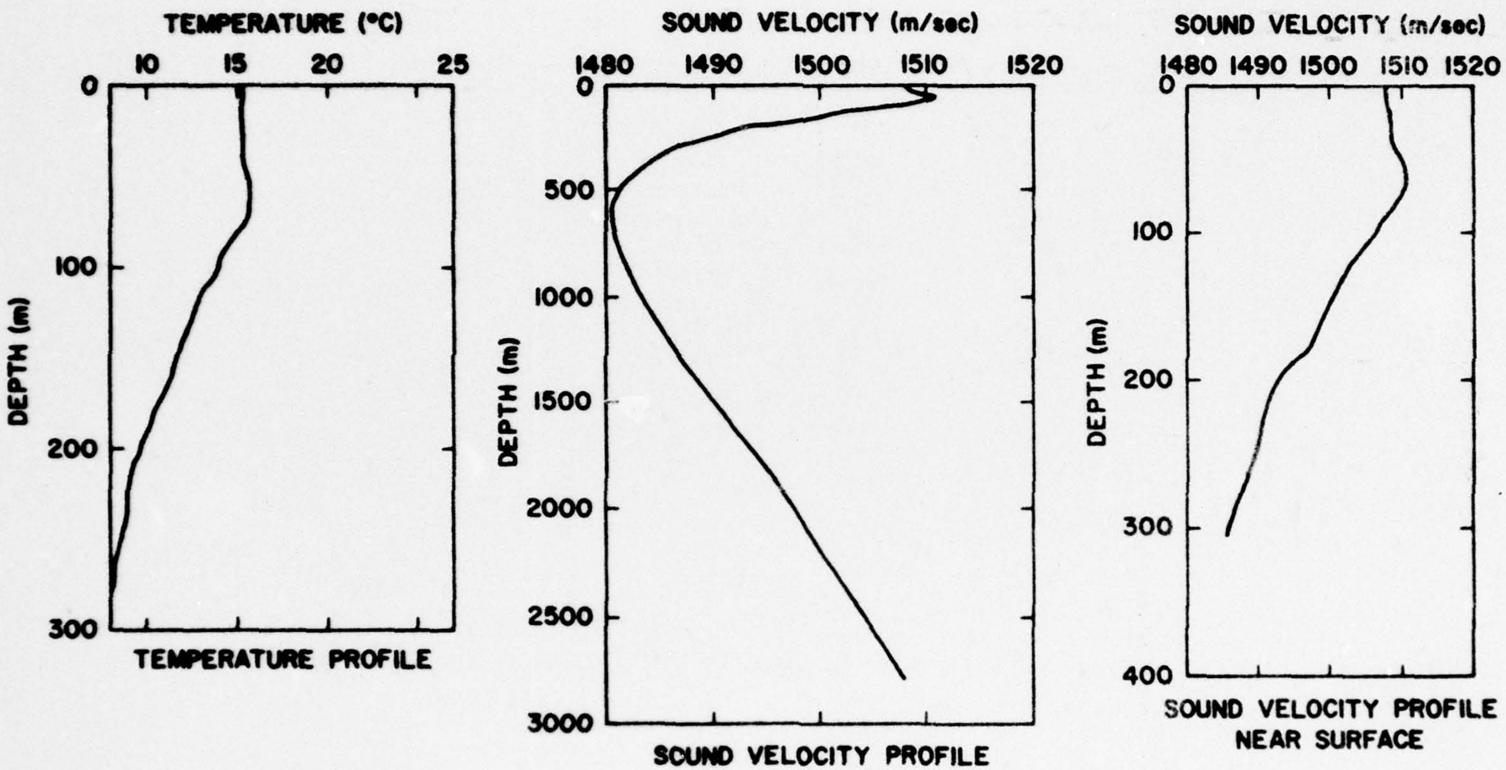

Figure 5. Slope water temperature and sound velocity profiles

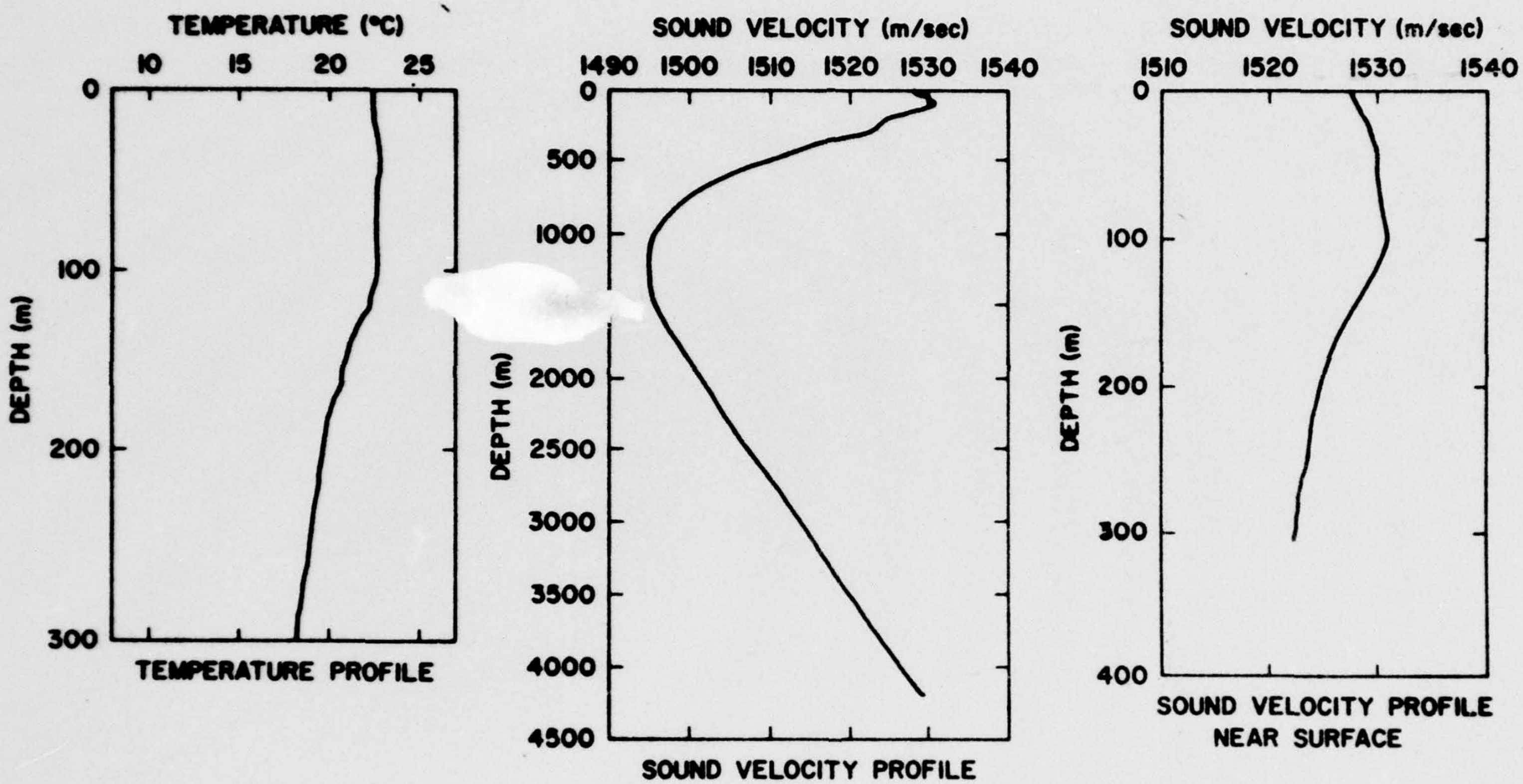

Figure 6. Gulf stream temperature and sound velocity profiles

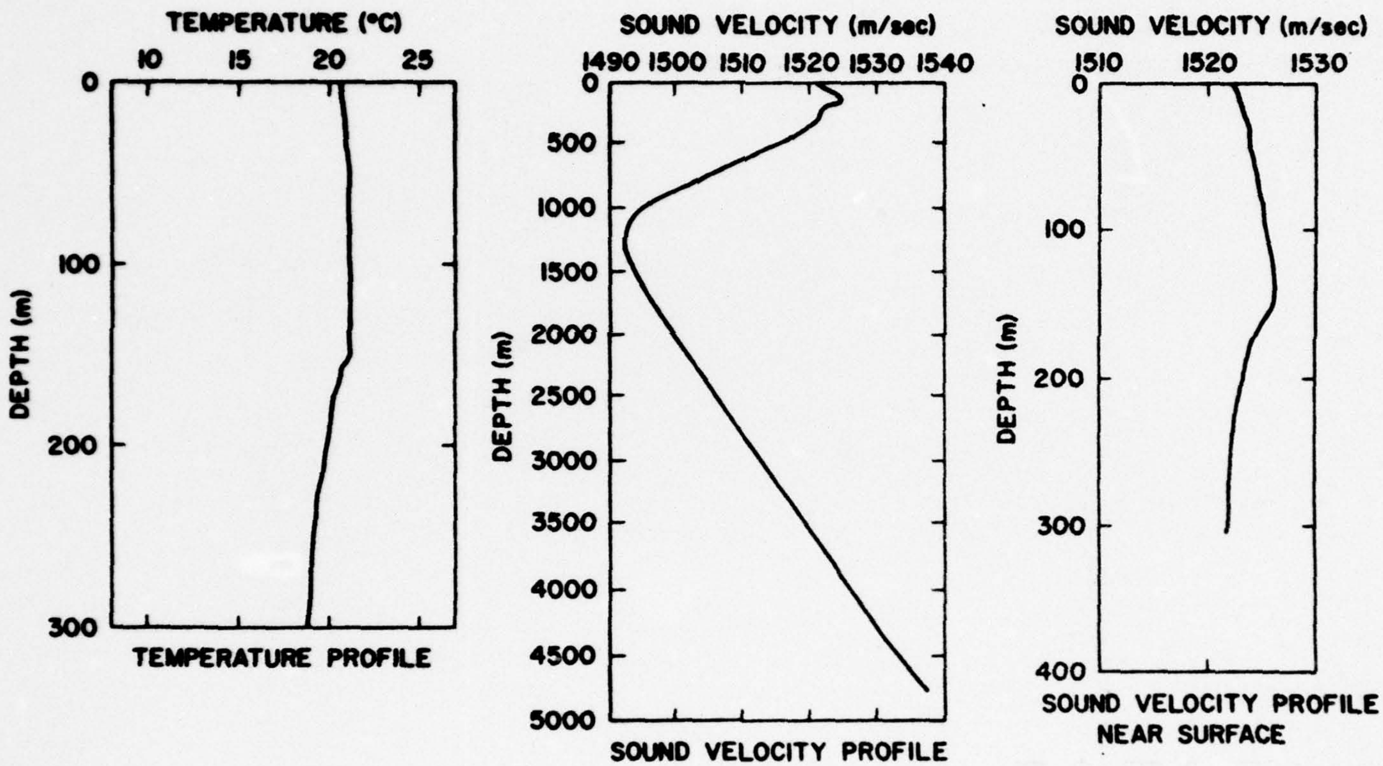

Figure 7. Sargasso water temperature and sound velocity profiles

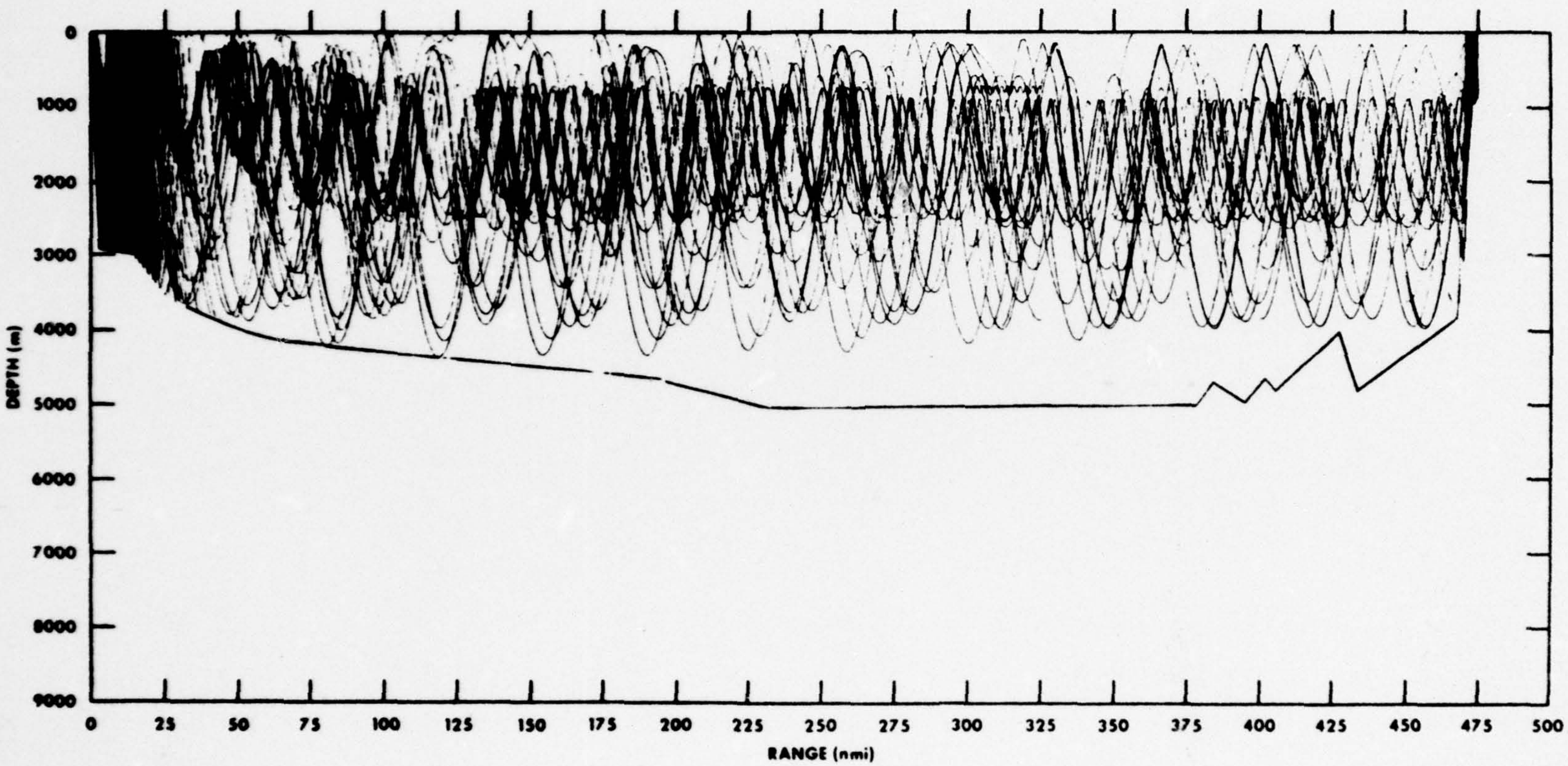

Figure 8. Ray plot from source in slope water to Bermuda hydrophones

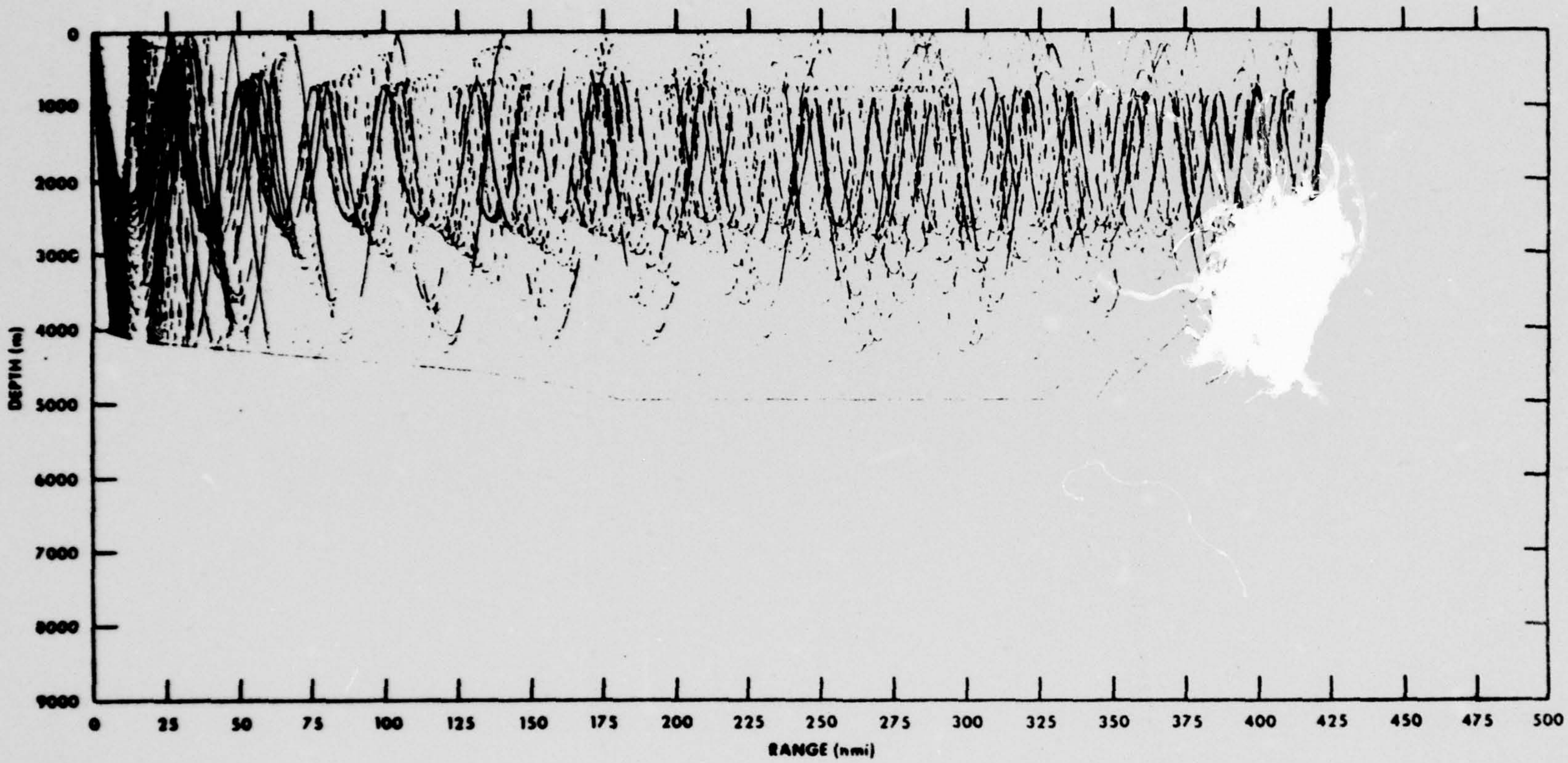

Figure 9. Ray plot from source near shot 425 to Bermuda hydrophones

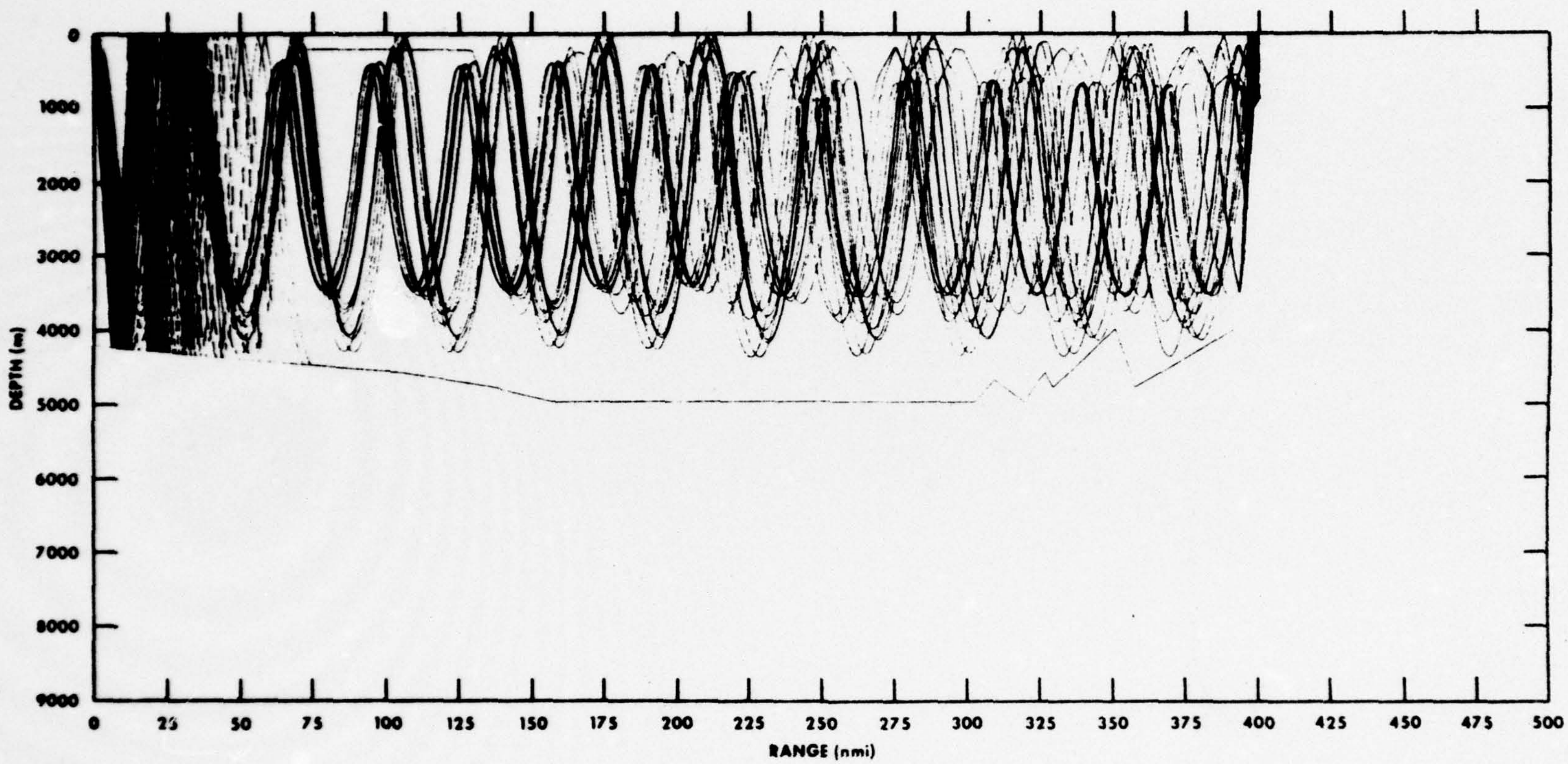

Figure 10. Ray plot from source near shot 422 to Bermuda hydrophones

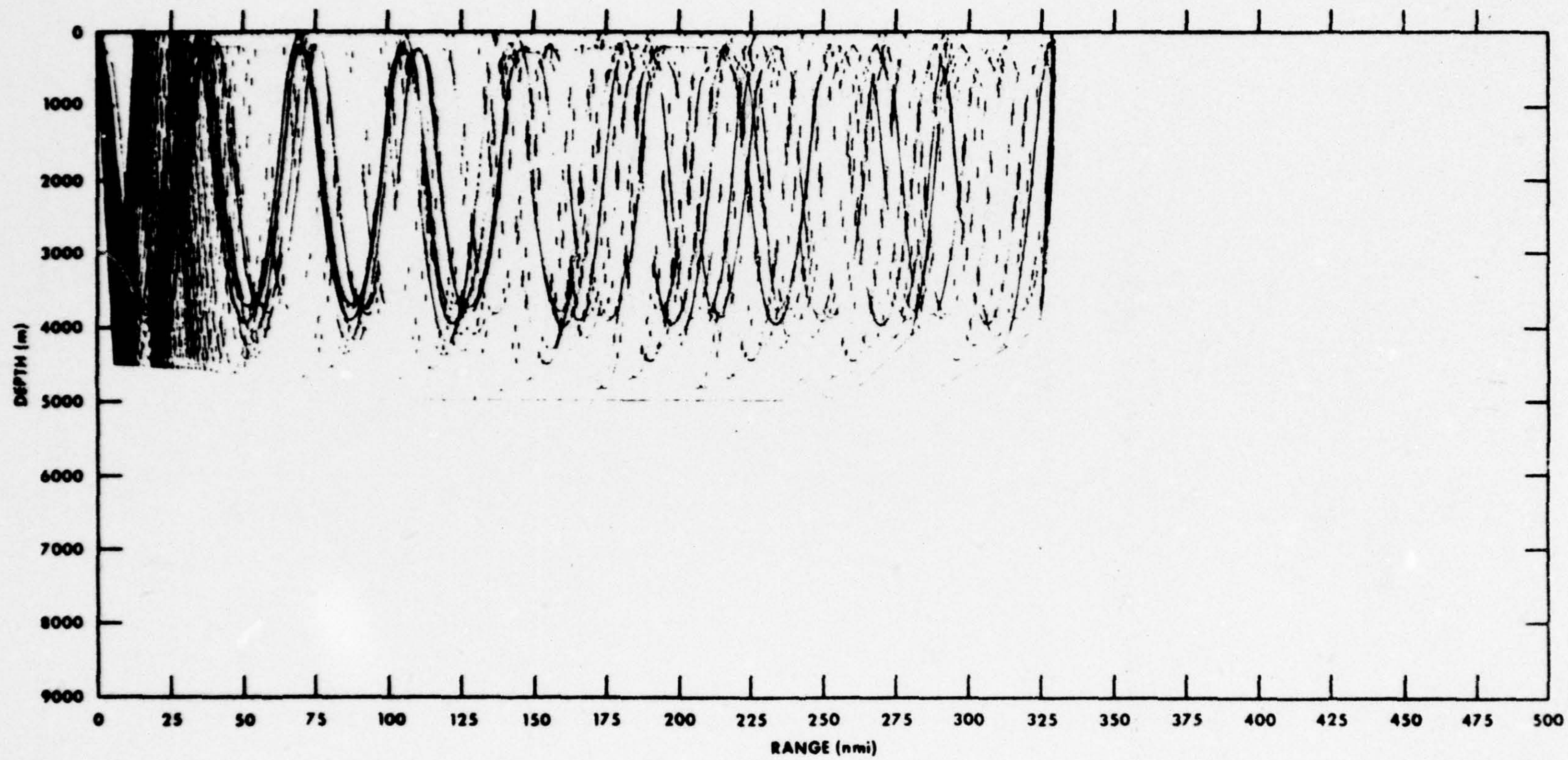

Figure 11. Ray plot from source near shot 413 to Bermuda hydrophones

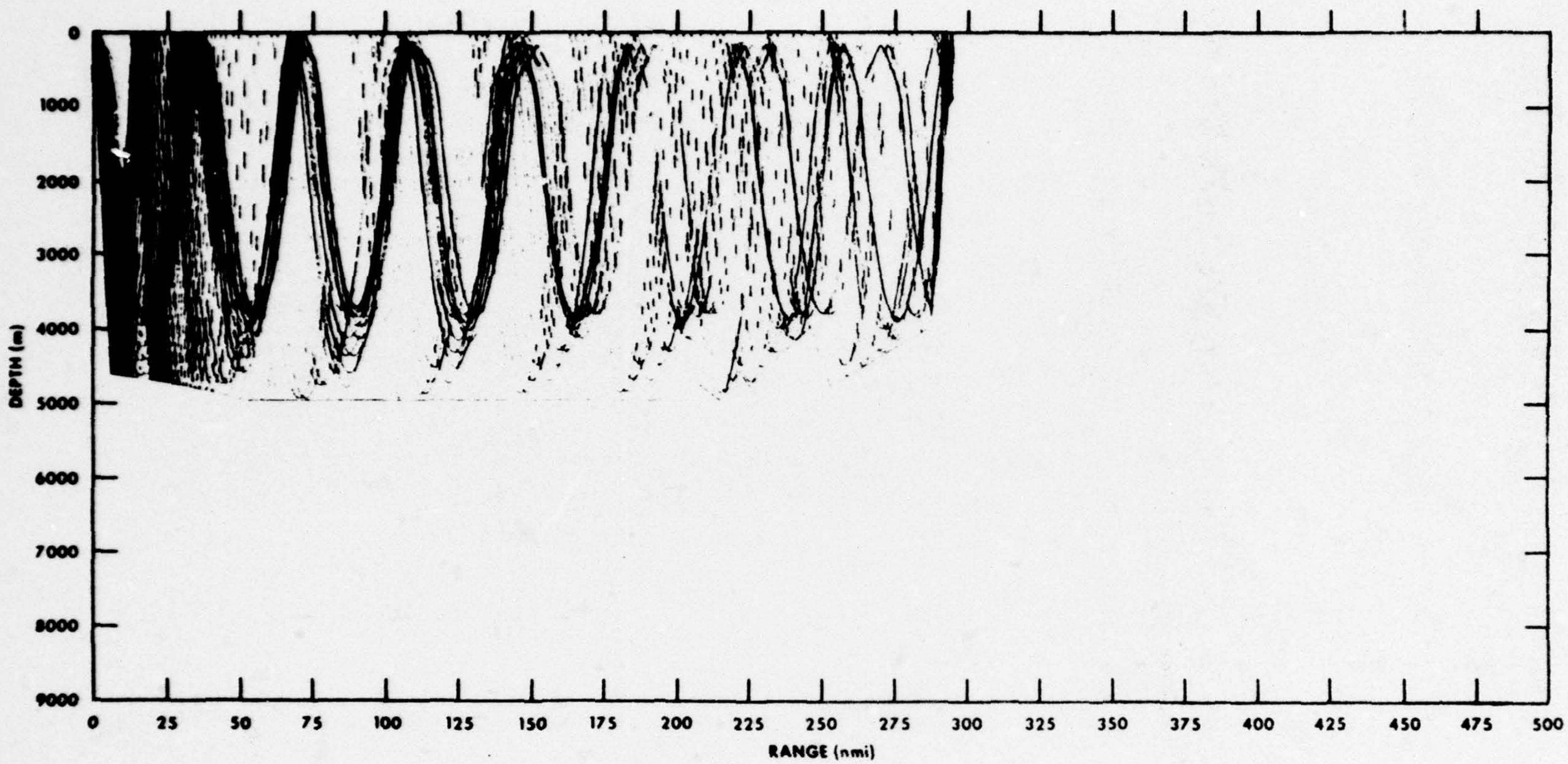

Figure 12. Ray plot from source in Sargasso Sea to Bermuda hydrophones